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USSR Report

MATERIALS SCIENCE AND METALLURGY

(FOUO 4/81)



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CONTENTS

ANALYSIS AND TESTING

Evaluating Crack Resistance of Structural Materials..... 1

COMPOSITE MATERIALS

Antifriction Properties of Fluoropolymer-Base Composition
Materials..... 6

HEAT RESISTANT ALLOYS

Heat Resistance of Alloys for Gas Turbine Engines..... 11

Processing Lightweight and Heat-Resistant Alloys..... 15

MECHANICAL PROPERTIES

Strength, Plasticity of Materials in Radiation Fluxes..... 20

REFRACTORY MATERIALS

Precipitation Hardening of High-Melting Metals..... 23

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ANALYSIS AND TESTING

UDC: 539.37:620.17:620.19

EVALUATING CRACK RESISTANCE OF STRUCTURAL MATERIALS

Kiev METODY I SREDSTVA OTSENKI TRESHCHINOSTOYKOSTI KONSTRUKSIONNYKH MATERIALOV in Russian 1981 (signed to press 12 Dec 80) pp 3-4, 301-303

[Foreword and table of contents from book "Methods and Means of Evaluating the Crack Resistance of Structural Materials", edited by V. V. Panasyuk, Izdatel'stvo "Naukova dumka", 1500 copies, 303 pages]

[Text] Contents	Page
Foreword	3
Analytic Methods of Evaluating the Crack Resistance of Materials	
Panasyuk, V. V.; Andreykiv, A. Ye., Kovchik, S. Ye.; Zazulyak, V. A.; Pan'ko, I. N.; and Nagirnyy, R. V. Establishment of the Conditions of Applicability of Irwin's Criterion.....	5
Method of Determining Crack Resistance of Materials K_{Ic} in Bending a Cylindrical Specimen With an Annular Crack	11
Method of Evaluating the Crack Resistance of Structural Materials in Stretching and Bending a Cylindrical Specimen With an Exterior Annular Crack Coming to the Surface of a Ring Concentrator.....	19
Yarema, S. Ya. Investigation of Disk Specimens With a Crack	25
Ivanitskaya, G. S. Stability of the Trajectory of a Fatigue in a Disk Specimen	44
Stadnik, M. M. Analytic Investigation of the Kinetics of Growth of an Interior Fatigue Crack in an Infinite Cylinder	52
Methods of Stabilization of the Coefficient of Intensity of Stresses Around the Point of a Growing Crack	57
Andreykiv, A. Ye. Calculated Model of Local Failure of Elastico-Plastic Bodies With Cracks	63
Method of Determining the Kinetics of Growth of an Exterior Crack in an Infinite Cylinder Under Cyclic Loading	73
Stadnik, M. M. Plotting a K_I Calibration for a Force Diagram of Bending of a Prismatic Bar With a Circular Crack	78
Method of Determining the Crack Resistance of Materials During Four-Point Bending of a Cylindrical Specimen With an Exterior Annular Crack	81

FOR OFFICIAL USE ONLY

Evaluation of the Crack Resistance of Materials During Short-Duration Loading	
Method of Determining Fracture Toughness (Crack Resistance) K_{Ic} of Structural Materials Under Static Loading	87
Zazulyak, V. A. One Approach to Plotting Temperature Relations of K_{Ic}	96
Method of Evaluating Fracture Toughness on Cylindrical Specimens With a Helical Concentrator During Torsion Testing	102
Method of Determining Fracture Toughness K_{Ic} on Cylindrical Specimens With Segmental Concentrator	108
Maksimovich, G. G., and Fedirko, V. N. Estimating Resistance to Crack Propagation on Small Plane Specimens	115
Method of Determining Characteristics of Crack Resistance of Welded Joints of Unlike Materials	119
Panasyuk, V. V.; Kovchik, S. Ye., and Khodan', I. V. Estimating Tendency Toward Brittle Failure of Structural Materials Under Shock Loading	122
Method of Estimating Fracture Toughness of High-Strength Materials Inclined to Delayed Failure	136
Gnyp, I. P.; Pokhmurskiy, V. I.; Bakshi, O. A.; and Shron, R. Z. Estimating Fracture Toughness of Low-Strength Metals by the Soft Interlayer Method	139
Microfractographic Method of Estimating Fracture Toughness of Patented High-Strength Steel Wire	145
Petrina, Yu. D., and Lenets, N. A. Method of Forming Cracks on Specimens Intended for Estimating Fracture Toughness	152
Romaniv, O. N. Method of Formation of Annular Cracks on Cylindrical Specimens Intended for Estimating Resistance of Metal to Brittle Failure	155
Maksimovich, G. G.; Fedirko, V. N.; and Skitskiy, R. Yu. One Method of Formation of Cracks on Flat Specimens	159
Zazulyak, V. A., and Mikitishin, S. I. Method of Formation of Axisymmetric Cracks in Cylindrical Specimens	162
Automated Unit for Producing Cracks in Cylindrical Specimens	167
Device for Producing Artificial Cracks With a Rectilinear Front in Prismatic and Compact Specimens	170
Guillery Impact Machine	174
Estimating Crack Resistance of Materials Under Cyclic Loading	
Yarema, S. Ya. Growth of Fatigue Cracks (Methodological Aspects of Investigation)	177
Method of Determining Cyclic Fracture Toughness of Materials	207
Method of Plotting Cyclic Fracture Diagrams in Conditions of Plane Strain ..	212
Method of Stabilizing a Stressed-Strained State Around the Point of a Fatigue Crack in Specimens During Pure Bending	220
Method of Investigating Propagation of Fatigue Cracks in Prismatic Specimens With a Constant Coefficient of Stress Intensity	226
Simin'kovich, V. N.; Gladkiy, Ya. N.; and Deyev, N. A. Plotting Kinetic Fatigue Diagrams Based on Test Results on a Machine With Rigid Loading of Specimens of Differing Thickness	228
Ostash, O. P. Features of Method of Investigating Kinetics of Low-Temperature Fatigue Failure	231
Tension-Compression Machine For Fatigue Testing at Transresonance Frequencies ..	234
Device for Testing Cyclic Crack Resistance of Materials in Conditions of Controlled Change of ΔK Level	238

FOR OFFICIAL USE ONLY

Machines for Testing Cyclic Crack Resistance of Structural Alloys	241
Machine for Testing Fatigue Failure of Beam Specimens	246
Methods of Mechanics of Corrosion Failure	
Romaniv, O. N., and Nikiforchin, G. N. Features of Kinetic Diagrams of Corrosion Cracking of Structural Alloys	251
Nikiforchin, G. N., and Student, A. Z. Utilization of Nonlinear Mechanics of Failure for Estimating Resistance to Growth of Corrosion Cracks	258
Method of Investigating Corrosion Cracking of Structural Materials in Conditions of Antiplane Deformation	262
Romaniv, O. N.; Nikiforchin, G. N.; and Berezyuk, I. A. Principles of Design of Testing Devices With Rigid Loading by Means of an Elastic Element	268
Device for Investigating Fatigue Crack Kinetics in Specimens During Pure Bending in Liquid Media	275
Test Device for Investigating Fatigue Crack Kinetics in Aqueous Media of Medium Parameters	278
Device With Automatic Load Control for Investigating Corrosion Cracking of Materials	282
Device for Investigating Protracted Static Crack Resistance in Working Media	286
Device for Testing Large Specimens for Delayed Failure	289
Device for Obtaining a Temperature, Pressure and Moisture-Stable Gaseous Medium	291
Chamber for Investigating the Crack Resistance Parameters of Structural Materials in Controlled Gaseous Media	296
Shpitser, K. M. Method of Investigating Cyclic Crack Resistance in an Environment Under Pressure	296

FOREWORD

Interest in the problem failure of materials has been steadily growing during the last two or three decades, and rapid growth and development of research is observed in this field of science. This has been caused to a significant degree by the practical importance of this problem and, in particular, its great significance for developing methods of estimating the durability of a material in a structure under given conditions of operation, as well as for forming the principles of controlling the strength of structural materials.

Intensive advance in elaboration of the problem of failure of materials became possible as a result of new approaches to treatment of this phenomenon as a phenomenon of crack formation and development, and as a result of elaboration of effective mathematical and physical methods of analysis of stressed-deformed states in a deformable solid. Of special significance in this area are new failure criteria based on the concepts of density of fracture energy, coefficients of stress intensity, critical crack opening, etc. They have become the basis of fundamentally new methodological approaches in determining the durability of structural materials under specified extreme operating conditions. These approaches have made it possible to adopt the concept of crack resistance in engineering practice, that is, the characteristics of a material's resistance to the development of cracks, as well as the values of critical and threshold coefficients of intensity of stresses,

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critical or maximum crack opening, diagrams of rate of crack growth during protracted cyclic or static loading, etc. The practical significance of crack resistance characteristics for engineering practice is indicated by the fact that in some technologically developed countries steps are being taken to standardized methods of determining crack resistance characteristics in order to provide adequate attestation and ranking of structural materials on the basis of resistance to crack propagation.

A new field of study of strength of materials has formed in this area -- mechanics of failure, the development of which originated in study of concentration of stresses alongside cavities and apertures in an elastic continuum. In the 1950's this area of investigation was intensively developed by scientists at the Ukrainian SSR Academy of Sciences Institute of Engineering Science and Automatic Control (presently the Ukrainian SSR Academy of Sciences Physicomechanical Institute) under the direction of Ukrainian SSR Academy of Sciences Academician G. N. Savin and Professor M. Ya. Leonov. This resulted in publication of the first studies on theory of cracks, estimate of the elastico-plastic situation at the apex of a quasi-brittle body, as well as limit equilibrium of brittle bodies with cracks. The first Soviet monograph dealing with this latter subject was published in 1968.* The now widely known σ_k criterion of limit equilibrium and crack resistance of structural materials was formulated in the first studies on theory of cracks.

Methods of estimating the effective surface fracture energy, which are something of an analog of methods of estimating the now well-known parameter of specific intensity of fracture energy G_{IC} , were elaborated in the mid-1960's at the Ukrainian SSSR Academy of Sciences Physicomechanical Institute. A number of studies at the Institute laid down the methodological groundwork for the nonlinear criterion of failure, which is being intensively developed today, a criterion which was designated J-integral. As a result of fruitful activity by the Ukrainian SSR Academy of Sciences Physicomechanical Institute in the area of mechanics of failure, more than 200 different items were published (including monographs), in which theoretical and applied developments in this area of science are synthesized.

Taking into consideration the practical possibility of research in the area of mechanics of failure, the Institute devotes considerable attention to new methodological developments in estimating the crack resistance of structural materials, including both the development of new methods and experimental means for estimating the crack resistance of materials.

This volume presents retrospectively the most important methodological achievements in estimating a material's resistance to the propagation of cracks under the most diversified conditions of loading, results obtained in recent years at the Ukrainian SSR Academy of Sciences Physicomechanical Institute.

All articles in this volume are grouped in four sections according to methodological thrust and functional significance in estimating crack resistance. The first section contains articles which present the analytic basis of a number of new methods

* Panasyuk, V. V., "Predel'noye ravnovesiye khrupkikh tel s treshchinami" [Limit Equilibrium of Brittle Bodies With Cracks], Kiev, Naukova Dumka, 1968, 246 pages.

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of estimating a material's resistance to crack propagation. Alongside establishment and development of conditions of applicability of failure criteria, the articles in this section present calculated relations for estimating crack resistance in objects of a cylindrical type with an exterior and interior cracks, as well as in special specimens of a disk type, on which it is comparatively easy to secure stabilization of coefficients of intensity of stresses in the process of crack growth.

The second section reflects the diversified activities of the Institute's experts in creating and improving experimental methods of estimating brief-duration crack resistance (fracture toughness) of metals and alloys. These methods provide a substantial measure of experimental confirmation to the analytic solutions developed at the Institute. Some articles in this section deal with development and improvement of techniques of inducing fatigue cracks, which provide an adequate estimate of crack resistance (fracture toughness).

The third section deals with development of methods and techniques of estimating long-term crack resistance of structural materials under cyclic loading. In addition to construction and interpretation of fatigue failure diagrams, the articles describe design features and operating principles of various testing devices for studying the kinetics of crack growth under protracted cyclic loading.

The fourth section deals with the methodological aspects of the youngest and inadequately elaborated problem of mechanics of failure, pertaining to growth of cracks under the effect of static loads and aggressive media. Development of these problems is of particular engineering significance in connection with the determined radical effect on crack growth of gaseous and liquid media which are recognized as inert or low-activity in estimating the load-carrying capacity of items not containing cracklike concentrators. A characteristic feature of a number of approaches and methods described in this volume is their extensive analytic line of reasoning and practical effectiveness, which enables one to recommend them as a basis for drafting standards for determining the crack resistance of metals and alloys.

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COMPOSITE MATERIALS

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ANTIFRICTION PROPERTIES OF FLUOROPOLYMER-BASE COMPOSITION MATERIALS

Moscow ANTIFRIKTSIONNIYE SVOYSTVA KOMPOZITSIONNYKH MATERIALOV NA OSNOVE FTORPOLIMEROV
in Russian 1981 pp 2-4, 146-147

[Annotation, foreword and table of contents from book "Antifriction Properties of Fluoropolymer Base Composition Materials", by N. P. Istomin and A. P. Semenov, Izdatel'stvo "Nauka", 147 pages]

[Text] Annotation

This monograph gives the results of the study of friction and wear without lubrication using fluoropolymers and fluoropolymer-base composition materials. Installations and testing methods are described. Data on various technological processes for obtaining fluoroplastic-4-base composition materials are cited. The results of the effect of a number of factors on the friction and wear of fluoropolymers, as well as of the introduction of various fillers into polymers are considered. Data are cited on the friction and wear of metal-fluoroplastic materials and fluoroplastic-4MB-base composition materials.

This book is intended for scientific staff workers, engineers and designers involved in solving problems of friction, wear and lubrication.

The book contains 14 tables and 61 illustrations. The bibliography lists 172 items.

Foreword

The use of polymer materials at friction joints had already become widespread in the thirties. At first, they were phenolic tar-base plastics such as textolite or laminated wood plastics. Then polyamide tars and their compounds with other substances appeared and began to be used as antifriction materials. All these materials are efficient only with lubrication, including lubrication with water and, under certain condition, have important advantages over metal materials.

In the fifties to the seventies, due to the development of chemistry and, in particular, the rapid development of fluorine chemistry [1-6], it became possible to obtain, on an industrial scale, a whole series of entirely new synthetic fluoropolymers. Among such materials, polytetrafluoroethylene [PTFE], or fluoroplastic-4, has a unique complex of properties. One of the most valuable properties of fluoroplastic-4 is that its friction coefficient with other materials without

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lubrication and with fluoroplastic-4 itself is low (at low sliding velocity it does not exceed 0.05). It was precisely because of this property that fluoroplastic-4 is being used as an antifriction material; however, in its pure form it has limited application because of its low wear resistance and low mechanical properties. The "inherent" antifriction properties of fluoroplastic-4, however, may be used in various methods including creating composition materials on its basis whose friction coefficients remain close to those of pure fluoroplastic-4, while the wear resistance when operating without lubrication is increased many times and, at the same time, other physico-mechanical properties (strength, heat conductivity etc.) necessary for bearing materials are improved.

The development and introduction of increasing scales of antifriction materials not requiring lubrication are urgent problems in modern and future technology. The possibility of operating individual machine units and entire machines without lubrication is very desirable in the majority of cases, while in some cases -- extremely necessary. This makes it possible to save large amounts of lubrication materials, simplifies machine design, reduces operating costs and facilitates an increase in production efficiency. In a number of cases, these materials are the single acceptable solution of the problems faced by designers.

The development of new materials able to operate without lubrication, and the improvement of materials already available, are impossible without corresponding investigations of, and finding methods for increasing wear resistance and improving the antifriction properties of materials by improving their composition and the technology for their manufacture.

In this book being offered to the reader, the results are correlated of investigations made at the USSR Academy of Sciences Machinery Science Institute imeni A. A. Blagonravov on friction and wear without lubrication of fluoroplastic-4 and composition materials on its basis. The results of broad investigations are given, using a single method, of the effects of velocity, load, temperature, degree of crystallization; the action of penetrating radiation on friction and the wear of fluoroplastic-4 without fillers, as well as the effect of composition materials on antifriction properties based on fluoroplastic-4 with fillers (their chemical nature, composition, concentration, degree of dispersion, shape of particles and their orientation), and the technological processes for obtaining these composition materials. Besides fluoroplastic-4 and its compositions with various fillers, several other fluoropolymers were investigated and the possibility of utilizing them to obtain antifriction materials that operate without lubrication was considered.

On the basis of the obtained results, a number of governing laws were established that make it possible to select better substantiated fillers and technological processes to obtain materials (on the basis of fluoropolymers) with a given complex of properties that have a wear resistance hundreds and thousands of times greater than fluoroplastic-4 for concrete operating conditions.

The authors are grateful to Z. M. Yermakova and P. G. Babicheva who participated in making the tests and processing the results. The authors honor the memory of professor M. M. Khrushchev, doctor of technical sciences, who initiated the investigations, the results of which are given in this monograph.

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Table of Contents

Foreword	Page 3
Chapter 1. Fluoropolymer properties	5
1.1. Certain information on fluorine, fluorocarbon and fluoropolymers	5
1.2. Fluoroplastic-4, its chemical, physico-mechanical, technological and operating properties	6
1.3. Antifriction properties of fluoroplastic-4	15
1.4. PTFE modifications	21
1.5. PTFE copolymers	23
Chapter 2. Antifriction materials containing fluoroplastic-4	26
2.1. Methods for utilizing the antifriction properties of fluoroplastic-4	26
2.1.1. Use of fluoroplastic-4-base materials in the form of coatings	27
2.1.2. Use of fluoroplastic-4 in the form of woven cloth	28
2.1.3. Materials with fluoroplastic-4 introduced into a porous body	29
2.1.4. Metal-fluoroplastic ribbon materials with a steel structural base	31
2.2. Fluoroplastic-4-base composition materials (filled fluoroplastics)	33
2.2.1. Materials manufactured abroad and in the Soviet Union	35
2.2.2. Review of papers devoted to investigation of PTFE-base composition materials	45
2.3. Investigation problems	56
Chapter 3. Installations and methods for friction and wear testing	58
3.1. IP-3 machine	
3.1.1. General characteristics and design	58
3.1.2. Measuring device for determining the friction coefficient	63
3.1.3. Error determination in measuring the friction force	65
3.1.4. Error determination in measuring the normal load in the hydraulic loading device	66

FOR OFFICIAL USE ONLY

Table of Contents (Continued)	Page
3.2. Method for testing on the IP-3 machine using the friction shaft-flat sample arrangement	67
3.3. Machine for testing friction using an arrangement of a rotating sphere-annular sample	71
3.4. Method for testing friction using an arrangement of a rotating sphere-annular sample	72
Chapter 4. Investigation of friction and wear of fluoropolymers	73
4.1. Effect of load, velocity and temperature on friction and wear of fluoroplastic-4	73
4.2. Effect of degree of crystallization on friction and wear of fluoroplastic-4	80
4.3. Effect of penetrating radiation on friction and wear of fluoroplastic-4	82
4.4. Friction and wear of several PTFE copolymers	85
Chapter 5. Technology of manufacturing fluoroplastic-4-base composition materials	89
5.1. Using fluoroplastic-4 suspensions	89
5.2. Using fluoroplastic-4 powder	90
5.3. Pressing and sintering	92
Chapter 6. Investigation of friction and wear of fluoroplastic-4-base composition materials	96
6.1. Relationship between wear resistance and antifriction properties and the material of the filler, as well as its content in the composition	96
6.2. Effect of the degree of dispersion of fillers on the friction and wear of composition materials	107
6.2.1. Graphite and molybdenum disulfide	107
6.2.2. Silica	110
6.3. Effect of the structure and orientation of graphite particles cleavage planes	115
6.4. Effect of various graphite brands	120
6.5. Effect of shapes of bronze particles	122
6.6. Effect of lead	123
6.7. Complex fluoroplastic-4-base composition materials	128

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Table of Contents (continued)	Page
Chapter 7. Investigation of friction and wear of fluoroplastic- 4MB-base composition materials	129
Conclusion	135
Bibliography	139

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2291

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HEAT RESISTANT ALLOYS

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HEAT RESISTANCE OF ALLOYS FOR GAS TURBINE ENGINES

Moscow ZHAROPROCHNOST' SPLAVOV DLYA GAZOTURBINNYKH DVIGATELEY in Russian 1981
(signed to press 22 Oct 80) pp 3-6

[Table of contents, foreword and introduction from book "Heat Resistance of Alloys for Gas Turbine Engines", by Radiy Yevgen'yevich Shalin, Igor' Petrovich Bulygin, and Yevgeniy Rostislavovich Golubovskiy, Izdatel'stvo "Metallurgiya", 1,500 copies, 120 pages]

[Text] Table of Contents	Page
Foreword	4
Introduction	5
Chapter 1. Principle of Selection of Melts for Estimating the Grade Characteristics of Heat Resistance	7
Probability Approach to Estimating Heat Resistance Characteristics	7
Selection of Melts Characterizing the Grade of a Melt, According to Output Check Data	18
Chapter 2. Patterns of Change in Variance of Heat Resistance Characteristics	23
Variance in Time to Failure	24
Variance in Plasticity Limit	33
Variance in Creep Characteristics	35
Estimate of Average and Minimum Values of Heat Resistance Characteristics in the Area of Experiment	38
Deviations from Logarithmically Normal Distribution of Heat Resistance Characteristics	43
Chapter 3. Temperature-Power Relationship of Heat Resistance Characteristics	44
Long-Time Strength and Creep Limit	45
Plasticity Limit	61
Creep Rate and Isochronous Creep Curves	64

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FOR OFFICIAL USE ONLY

Chapter 4. Forecasting Average and Minimum Grade Values of Heat Resistance Characteristics	72
Long-Time Strength	73
Creep	77
Plasticity Limit	79
Chapter 5. Estimating Heat Resistance Characteristics Taking Account of Transient Conditions of Operation of a Material in a Structure	83
Influence of Transient Temperature and Power Conditions on Long-Time Strength	84
Application of Method of Experiment Mathematical Planning for Quantitative Estimate of Heat Resistance Characteristics	100
Appendix	113
Bibliography	117

FOREWORD

Improving the efficiency of societal production is a most important direction of party economic and technical policy advanced at the 25th CPSU Congress. One of the principal ways to achieve this objective, specified in party and government decisions, is to reduce the materials input in industrial products and securement of high product quality by extensive employment of advanced design solutions and proper utilization of materials, including ferrous and nonferrous metals and alloys, on the basis of a comprehensive, objective and precise evaluation of their properties.

Advance in the machine building industry is accompanied by speeding up the pace of improvement in operating parameters and increasing the load on structural components, with simultaneous increase in demands on product reliability and service life. In order to meet these demands it is essential to develop new, improved methods of evaluating the strength, reliability and durability of metallic materials produced by the metallurgical industry, with the objective of maximum utilization of their capabilities.

Several current tasks pertaining to this important problem, as applied to heat resistant alloys for a leading and intensively developing branch of power engineering machine building -- transport gas turbine engineering, are examined in this volume.

INTRODUCTION

Increasing demands on reliability and service life of gas turbine engines simultaneously with an improvement in their operating parameters evokes the necessity of developing optimal methods of estimating the strength properties of employed

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materials, with the objective of their fullest and most correct utilization. The basic criteria of properties of materials intended for extended operation at high temperatures include long-time strength and creep limit indices, utilized as calculated performance characteristics.

Extensive adoption of any grade of steel or alloy presupposes the manufacture of components of metal from different melts. Therefore in determining service life and margin of safety for commercial metal, the design engineer is interested not only in the average heat resistance indices of certain typical melts but also the performance of the target material as a whole (that is, grade characteristics), including standard deviation of strength properties and change in this figure in relation to length of service and level of operating temperature.

A lag in acquisition of information on the durability of materials in conditions of extended effect of stress-strain loads and high temperature, connected to a considerable degree with a substantial volume and considerable duration of laboratory testing for heat resistance, creates difficulties for design engineers and slows the rate of increase of product durability. In connection with this, development of reliable methods of predicting long-time strength and creep limit indices on the basis of the temperature-time relations of these indices and taking their variance into account, in spite of extensive research in this area remains a critical problem.

Questions connected with development and practical adoption of methods of statistical estimate and prediction of long-time strength and creep limit characteristics (including plasticity limit) are of particular importance for the class of high-heat-resistant alloys employed for power components of transport (especially aviation) gas turbine engines (GTE), for the following reasons:

- increased demands on reliability of critical structural components;
- high thermal and mechanical stress on parts;
- limited design and development timetable and rapid product replacement;
- continuous increase in service life;
- specific features of this class of materials.

The last of the above-listed factors is of great importance in regard to the problems under discussion.

For the most part complex nickel-base heterophase alloys with a clearly-marked structural instability in the range of operating temperatures are presently employed in the manufacture of such GTE components as turbine wheels and blades. Also characteristic of these alloys is a variability of manufacturing technology, caused by improvement in manufacturing processes [1] and variation in heat treatment of specific semimanufactures and finished products. In this case one can expect reliable results only with a statistical approach to estimating heat resistance characteristics and employment of temperature-time (temperature-power) relations

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which reflect the structural features of a material for predicting these characteristics.

At the same time melts of this class, and especially the group of new high-heat-resistant foundry alloys of the ZhS family which head this class, a typical representative of which is the ZhS6U alloy [2], which is produced in quantity, are the most interesting and representative objects of investigation in connection with the above features.

The development of new engines involves the adoption of cooled turbine moving and nozzle blades. In this area casting alloys are for all practical purposes displacing forming alloys, since they possess greater resistance and provide a better capability to produce hollow cooled blades.

In this volume the authors examine the methods and practical results of solving a number of basic problems pertaining to statistical estimation and prediction of long-time strength and creep limit indices of high-heat-resistant alloys employed in propulsion engineering.

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3024

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PROCESSING LIGHTWEIGHT AND HEAT-RESISTANT ALLOYS

Moscow PROTSSESY OBRABOTKI LEGKIKH I ZHAROPROCHNYKH SPLAVOV in Russian 1981
pp 2, 5-6, 260-262

[Annotation, table of contents, and foreword from book "Processing of Lightweight and Heat-Resistant Alloys", edited by Academician N. M. Zhavoronkov, Izdatel'stvo "Nauka", 262 pages]

[Text] This volume extensively discusses the scientific and technical school developed by Academician A. F. Belov, who celebrates his 75th birthday in 1981, by his students and disciples. This volume contains the results of most recent investigations in the area of casting, pressure shaping and heat treatment of aluminum, magnesium, titanium, heat-resistant and refractory alloys; contemporary problems of physical metallurgy, metallurgy and processing technology are examined. This volume contains extensive materials dealing with obtaining metal blanks and workpieces by methods of high-speed crystallization and hot isostatic pressure forging.

This volume is intended for research scientists, design engineers and metallurgical production specialists, physical metallurgists, process engineers, designers, machine builders, and students in the appropriate fields of specialization.

Contents	Page
75th Birthday of Academician A. F. Belov	3
Foreword	5
I. General Problems of Working and Treating Lightweight and Heat-Resistant Alloys	7
A. I. Tselikov and V. G. Trishkin. Modern Equipment for Working Lightweight and Heat-Resistant Alloys with Utilization of High Pressure and Temperature	7
V. S. Rakovskiy. Latest Advances in Powder Metallurgy in the Manufacture of Mass-Production Items for the Machine-Building Industry	14
N. N. Rykalin, Yu. L. Krasulin, and O. A. Batanova. On Thermal Stresses in Powders Produced With High Cooling Rates	19

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FOR OFFICIAL USE ONLY

F. V. Tulyankin, and V. P. Vasil'kovskiy. New Stage in the Development of Pressure Forging Technology	25
B. V. Rozanov and S. M. Topaler. Problems of Improving the Accuracy of Rolled Sheet and Automation of Rolling Mills on the Basis of Employment of Hydraulic Screwdown Gear	33
G. A. Nikolayev. Laser Welding	42
S. I. Kovalev and N. I. Koryagin. Influence of Friction Conditions in Rolling Laminated Sheet and Strip on Stresses Developing in the Layers	46
S. S. Kiparisov and V. K. Narva. Obtaining a Property and Employment of Wear-Resistant Titanium Carbide-Steel Materials	53
M. S. Gil'dengorn. Combined Pressure Forging of Metals of Differing Strength	59
M. S. Sirotinskiy. Cyclic Shear in Processes of Pressure Shaping Metals	65
S. A. Vigdorchik, A. V. Fishgoyt, and V. V. Luk'yanenko. Micromechanism of Propagation of Fatigue Crack in VT6, D16 and AK4-1 Alloys	69
II. Aluminum and Magnesium Alloys	77
N. A. Kaluzhskiy and V. P. Kiselev. Improving the Manufacturing Process and Quality of Products of Aluminum and Aluminum Alloys	77
V. I. Dobatkin, V. I. Yelagin, and G. A. Mudrenko. Study of the Structure and Properties of Alloys of Aluminum With Iron, Obtained With High Cooling Rates During Crystallization	82
I. N. Fridlyander, O. A. Setyukov, L. M. Sheveleva, and Z. A. Yelagina. Influence of Iron on the Structure and Properties of Aluminum Forging Alloy V93	91
B. S. Mitin, A. I. Kolpashnikov, A. V. Yefremov, S. S. Rodchenko, and A. S. Kirilyanchik. Investigation of Semimanufactures of Al-Mg Alloy System Granules	97
B. I. Bondarev, V. I. Napalkov, V. S. Chulkov, and V. S. Rozanova. Influence of Methods of Processing Aluminum Melts on the Quality of Semimanufactures	101
A. D. Andreyev, V. V. Gogin, and G. S. Makarov. Paths of Development of Deformable Aluminum Alloy Melting Technology	105
A. N. Chekanov. Multiple Ingot-Mold System With Graphite Molds for Casting Aluminum Alloy Ingots	110

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G. I. Eskin and P. N. Silayev. Employment of Ultrasonic Treating of a Melt During Crystallization of Large Ingots of High-Strength Aluminum Alloys	118
I. G. Kirpa, and Yu. N. Ponagaybo. Improving the Efficiency of Cold-Rolling Aluminum Alloy Strip	123
I. A. Shur, and G. V. Silanova. Continuous Working of Flat Rolled Stock of Aluminum Alloys	127
V. S. Sinyavskiy, V. I. Plokhov, V. M. Gladyshev, and F. P. Zalivalov. Investigation of the Mechanisms of Formation of a Stable Alloy-Polymer Film System in Laquering Aluminum Can Strip	133
I. P. Erlikh and G. V. Ryuchina. Employment of Rolled Aluminum in the Nation's Economy	140
M. Ye. Drits and L. L. Rokhlin. Damping Capability of Magnesium Alloys	144
III. Titanium, Heat-Resistant and Refractory Alloys	
A. F. Belov, N. F. Anoshkin, V. I. Khodkin, O. Kh. Fatkullin, V. A. Danilkin, G. S. Garibov, M. I. Rasshivalkin, A. A. Rogozinskiy. Investigation of Physicochemical Processes in the Manufacture of Heat-Resistant Nickel Alloy Pellets and Products of Them	151
S. Z. Bokshteyn, Ye. V. Bolberova, S. T. Kishkin, Yu. M. Mishin, and I. M. Razumovskiy. Features of Diffusion in Eutectic Alloys With Directional Structure	163
P. N. Belyanin and V. L. Arutyunov. New Processes of Manufacture of Parts and Assemblies of Sheet Titanium Alloys	171
Ye. M. Savitskiy and K. B. Povarova. New Developments in the Investigation of Tungsten Alloys	178
M. I. Karpov and Ch. V. Kopetskiy. Features of the Structure of Rolling-Deformed and Annealed Molybdenum	190
A. I. Baturin and V. B. Gusarev. Development of Processes of Electro-contact Treatment in the Production of Semimanufactures of Heat-Resistant Alloys	198
I. A. Kononov and V. T. Musiyenko. Process Features and Equipment for Obtaining Powders by the Method of Centrifugal Spraying of a Rotating Workpiece	205
Ye. P. Daneliya, I. P. Pazyuk, V. M. Rozenberg, and Yu. F. Shevakin. Relaxation of Stresses and Creep of Copper Hardened by Dispersed Oxides	212

FOR OFFICIAL USE ONLY

M. Z. Yermanok, Yu. P. Sobolev, G. M. Kuleshov, S. A. Katukov, and V. I. Feygin. Pressure Shaping Granulated Heat-Resistant Alloys	218
Yu. M. Sigalov, A. I. Kolpashnikov, V. N. Chernyshev, and V. S. Rakovskiy. Investigation of the Possibility of Rolling Sheet and Foil of Nickel and Titanium Alloy Powders and Granules	227
Ya. V. Ulanovskiy and G. I. Dubnik. The Problem of Forming the Structure of Foil Obtained by Vacuum Deposition	234
B. A. Kolachev, V. S. Lyasotskaya, R. G. Koknaye, and L. S. Krasno- yartseva. Preliminary Heat Treatment of Titanium Alloys	240
G. A. Bochvar, Ye. I. Oginskaya, and N. V. Yanovskaya. Influence of the Conditions of Phase Recrystallization on the Fatigue Strength of the Alloy VT5	248
I. S. Pol'kin. Features of Fracture of High-Strength Titanium Alloys	253

FOREWORD

This volume extensively discusses the scientific and technical innovations in metallurgy of lightweight and heat-resistant alloys developed by Academician Aleksandr Fedorovich Belov, who is celebrating his 75th birthday in 1981, and by his pupils and disciples.

The first section of this volume deals with general problems of treatment and working of lightweight and heat-resistant alloys. Prominent Soviet scientists -- metallurgists, physical metallurgists, machine builders, and experts in the field of powder metallurgy -- outline, on the basis of analysis of the present level of science and technology in high-grade metallurgy, the general paths of further development of advanced processes of working and treatment of metals and the development of equipment for processing lightweight and heat-resistant alloys with utilization of high pressures and temperatures. Also presented are the results of physical metallurgical investigations and studies in the area of theory of pressure shaping metals, which are of interest in studying the processes of working all alloys.

The second section of this volume deals with aluminum and magnesium alloys. It contains articles which encompass a broad range of questions, including improvement in production technology and product quality at aluminum industry enterprises, development prospects of the processes of blank casting, cold rolling, continuous processes of heat treatment and application of protective and decorative coatings on semifinished products of aluminum alloys. Articles examine the results of investigations of change in structure and properties in relation to the chemical composition of alloys and the conditions of various treatment processes; data are presented on the nature of fracture of alloys. Materials are included which deal with obtaining aluminum alloys by the high-speed crystallization method and this method's development prospects; various aspects of the quality of magnesium alloys are examined. Information is presented on the prospects of utilization of aluminum alloys in the nation's economy.

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The third section of this volume deals with investigations of titanium and heat-resistant alloys based on nickel and other nonferrous metals, as well as refractory metals. Of greatest interest are data pertaining to new methods of obtaining advanced metallic materials by the high-speed crystallization and hot isostatic pressure forging methods. Articles examine the complex physicochemical processes which take place during production and treatment of individual granules, during sintering of granules under the effect of high pressures and temperatures, and heat treatment of forming one-piece items. There is extensive discussion of investigation of various methods of obtaining and processing semimanufactures of titanium alloys, industrial processes of working and treating titanium, and the behavior of titanium parts in certain structures. This section contains materials pertaining to the physical metallurgy of molybdenum and tungsten.

On the whole the volume contains a good deal of new information in the area of processes of working and treating lightweight and heat-resistant alloys and points out the paths of future development of high-grade metallurgy. This volume will help further strengthen links between research scientists and industry and will promote effective utilization of scientific advances.

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STRENGTH, PLASTICITY OF MATERIALS IN RADIATION FLUXES

Kiev PROCHNOST' I PLASTICHNOST' MATERIALOV V RADIATIONNYKH POTOKAKH in Russian
1979 (signed to press 12 Dec 79) pp 3-4, 283-284

[Foreword and table of contents from book "Strength and Plasticity of Materials in
Radiation Fluxes", by Georgiy Stepanovich Pisarenko and Vladimir Nikolayevich
Kiselevskiy, Izdatel'stvo "Naukova dumka", 1400 copies, 284 pages]

[Text] Table of Contents	Page
- Foreword	3
- Chapter One. Methods of Experimental Investigation of the Mechanical Properties of Irradiated Materials	5
1. Principal Requirements on Irradiation Methods	6
2. Principles of Mechanical Loading During In-Reactor Investigations ...	8
3. Improved-Accuracy Hydraulic Method of Static Loading	23
4. Electromechanical Method of Cyclic Loading	32
5. Measuring Deformations During In-Reactor Tests	44
6. Heating Irradiated Specimens and Features of Measuring Their Temperature	63
Chapter Two. "Neytron" Test Equipment for Investigating the Mechanical Properties of Structural Materials	76
1. Neytron-1 and Neytron-3 Equipment for Studying Creep Limit and Creep Resistance	78
2. Neytron-2 and Neytron-4 Equipment for Stress-Strain Testing of Materials In a Plane Stressed State	94
3. Metrological Characteristics of Neytron Equipment for Investigating Creep and Creep Limit	103
4. Neytron-5 Equipment for Investigating Fatigue of Materials Under Small-Cycle Loading	111
5. Neytron-6 Device and Neytron-7 Equipment for Stress-Strain Testing of Materials in a Molten-Metal Medium and Dissociating Gas	125
Chapter Three. Resistance to Plastic Deformation and Failure of Irradiated Heat-Resisting Steels and Alloys	130

FOR OFFICIAL USE ONLY

1. Change in Strength Characteristics of Stainless Steels.....	130
2. Effect of Reactor Irradiation on Strength of Nickel Alloys	139
3. Change in Plastic Properties of Steels and Alloys. Effect of High-Tem- perature Radiation Embrittlement	146
4. Increasing Tendency of Steels Toward Brittle Failure	158
5. Creep Limit of Irradiated Steels and Alloys	170
6. Change in Creep Resistance of Irradiated Steels and Alloys	180
Chapter Four. Change in Mechanical Properties of Zirconium Alloys As a Result of Reactor Irradiation	190
1. Characteristics of Strength, Plasticity and Resistance to Brittle Failure of Irradiated Zirconium Alloys	190
2. Creep Resistance of Zirconium Alloys During In-Reactor Tests	201
Chapter Five. Phenomenological Model of Deformation and Failure of Ir- radiated Steels	216
1. Experimental Investigation of Hypotheses of Creep and Limiting State	216
2. Equation of the State of Steel During Creep	229
3. Experimental Verification of Creep Equations	239
4. Criterion of Creep Limit of Heat-Resisting Steel	251
5. Dependence of Creep Limit of Stainless Steel on Intensity and Energy Spectrum of Irradiation	255
Bibliography	266

FOREWORD

The development of nuclear power engineering makes it necessary to elaborate the scientific principles of strength calculations of structural components of the cores of nuclear reactors, and particularly the fuel elements, which determine the overall reliability and economy of reactors. Utilization of the reserve capability of materials able to resist loads under the complex conditions of thermal and radiation effects is possible only with availability of scientifically substantiated standards for calculating the components of the appropriate structures.

Modern technology of designing fuel elements calls for comprehensive investigation of the physicomaterial properties of fuel compositions and shell materials, as well as testing both of individual fuel element components and assemblies (for example, shells, ceramic plugs, rods, pellets, etc), and of structures as a whole in the form of fuel elements and their assemblages [131].

In the period 1955-1975 radiation materials science took shape as an independent science, which has had appreciable success in solving theoretical and applied problems of physics of radiation damage, and development of new materials possessing the requisite aggregate of physicomaterial properties. The obtained results enable one to resolve problems of application of individual types of materials under specified operating conditions.

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In the development of given structures, the stressed-deformed state and the maximum load-carrying capacity of their components at the given stage of development of strength physics should be calculated from the position of mechanics of a continuous medium, which is at an early stage of development for bodies sustaining radiation damage in the process of deformation.

Equations of the state of materials constructed on the basis of continuum mechanics, applicable to the applied aspects of mechanics of materials, are formulated by synthesizing the results of tests under conditions maximally approximating actual operating conditions. Investigation directly in radiation fluxes for the purpose of obtaining initial information on the behavior of irradiated materials under various conditions of thermomechanical effect involve substantial methodological difficulties, which impede the acquisition of corresponding equations of state.

In connection with this, there exists a certain indefiniteness in establishing the dimensions and shapes of fuel elements, an uncertainty which does not guarantee optimal initial models, which are subjected to subsequent fairly complex elaboration. The lack of scientifically substantiated strength standards requires adoption of large safety factors in calculations, which as a rule leads to a decrease in the neutron-physical characteristics of reactors, greater cost and, as a consequence, decreased technical-economic indices of nuclear equipment and power generating units as a whole. Therefore investigations of the properties of irradiated materials from the standpoint of mechanics of a continuous medium are conducted for the purpose of determining not only strength and plasticity characteristics but also the patterns of change in resistance to deformation and failure in relation to conditions of irradiation, type of stressed state, nature of application of load, temperature and other factors. Conduct of research as formulated above requires execution of special programs differing from the conventional programs of radiation of materials science.

In this study an attempt is made to resolve fundamental problems of methodology of in-reactor investigations of the mechanical properties of structural materials and synthesis of data on the influence of radioactive irradiation on the various characteristics of their resistance to deformation and failure, with the aim of establishing a number, kept within reasonable limits, of independent variables in the equations of state of materials under conditions of irradiation. A phenomenological model of creep of irradiated steels is presented, as well as a criterion of their maximum load-carrying capacity in a complex stressed state.

The methodological elaborations and research results presented in this monograph were obtained by the staff of the Ukrainian SSR Academy of Sciences Institute of Problems of Strength, under the supervision of and with the participation of the authors. In particular, the data examined in Section 3 of Chapter One and Section 1 of Chapter Two were obtained with the active participation of D. V. Polevoy and O. N. Yudin; Section 3 of Chapter One and Section 2 of Chapter Two -- V. K. Lukashev and G. P. Khristov; Section 4 of Chapter One and Section 4 of Chapter Two -- Yu. D. Skripnik; Section 5 of Chapter Two -- S. S. Tishchenko; Section 2 of Chapter Five -- B. D. Kosov and O. N. Yudin. The authors would like to express their profound gratitude to these contributors.

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PRECIPITATION HARDENING OF HIGH-MELTING METALS

Moscow DISPERSIONNOYE UPROCHNENIYE TUGOPLAVKIKH METALLOV in Russian 1980 (signed to press 26 Sep 80) pp 2-5, 303

[Annotation, introduction and table of contents from book "Precipitation Hardening of High-Melting Metals", by Vsevolod Konstantinovich Grigorovich and Yelena Naumovna Sheftel', edited by Professor O. A. Bannykh, doctor of technical sciences, Izdatel'stvo "Nauka", 1400 copies, 304 pages]

[Text] Annotation

An analysis of the crystalline structure and the physical and strength properties of transition metals that are the basis of most refractory alloys was made. This analysis was made from the standpoint of the electronic structure and chemical bond theory. The electronic-crystalline structure and the thermodynamic characteristics of high-melting compounds and their selection as precipitation-hardening phases are considered.

The physico-chemical principles of developing refractory alloys by combining a solid solution and precipitation hardening, as well as various methods for obtaining such refractory materials are described.

Patterns are considered of the precipitation hardening of niobium, vanadium, tantalum, chromium, molybdenum, tungsten and their alloys with high-melting carbides, nitrides and oxides of the transition metals of the fourth group.

This book is intended for a broad group of metal scientists, metallurgists, metal-physics scientists and production people who develop and use refractory materials in new areas of technology. It may be useful to students, graduate students and instructors in corresponding fields.

The book has 44 tables and 123 illustrations. The bibliography contains 563 titles.

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Introduction

The development of nuclear power engineering, aviation and space technology, radio-electronics, power and chemical machine-building, metallurgy and other sectors of industry demand the development of new refractory and heat-resistant materials that are more efficient than the steel and nickel alloys used widely at the present time. The most important, still unused, reserve of high-temperature structural materials are high-melting OTsK [Body-centered cubic] metals of the V - VI groups.

Exhaustive monographs by Soviet scientists are devoted to the metal science of vanadium, niobium, molybdenum, tungsten, chromium and their alloys [1-4 et al]. The physico-chemical principles of developing refractory alloys in connection with the phase (equilibrium) diagram, based on the teachings of academician N. S. Kurnakov were developed in correlating papers [5-8]. The structure and properties of high-melting metals and their alloys were considered in detail in monographs [9-12]. The theory and practice of the precipitation hardening of iron, nickel and cobalt were also described systemically [13-15]. However, the precipitation hardening of high-melting metals, which is the most important method for raising the heat-resistance of their alloys is still not adequately covered. The investigations of precipitation hardening of metals with carbides, nitrides, oxides and borides of the transition metals, published in periodicals, were analyzed in detail from the standpoint of metal science [11]; however, a systemization and further correlation of available data in the aspect of the electronic structure and physio-chemical alloy analysis are needed. This monograph attempts to fill this blank.

The stability of the crystalline structure, the thermodynamic and mechanical strength and heat resistance of high-melting metals are determined ultimately by inter-atomic bonds. The formation of strong, short metallic bonds between the closest atoms in tightly packed rows is considered a result of the overlapping of orbits of the outer collectivized electrons. In this case, the electron distribution in the actual lattice space that preserves the criteria of symmetry conforming to the atomic s-, p- and d- orbits or electronic clouds, corresponds to the s-, p- and d-zones. The excitation and fission of the basic p- framework shells lead to the formation of six covalent bonds localized on the framework and the OTsK structure of the high-melting metals. Assuming the symmetry of the outer collectivized framework of localized electrons, the following can be given a simple physical interpretation: the patterns of forming crystalline structures of metals and their polymorphic transformations, the preferred system of sliding at plastic deformation, the anisotropy of elastic modules, and many physical and mechanical properties of the metals. Such an analysis of the structure and properties of high-melting OTsK metals made it possible to interpret the patterns of the formation of the alloys of these metals in the aspect of the electronic structure.

The crystalline structure and properties of hardening phases and, especially, of high-melting, high-modulus carbides, nitrides, oxides and borides of transition metals are also due to the electronic structure of their atoms and the physical nature of interatomic bonds. The extremely high strength of the lattice of these compounds -- the extremely high temperatures of melting, heat of formation, extremely high hardness and strength -- are the direct result of the formation of strong, short covalent metal-interstitial element bonds that originate due to the

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overlapping framework shells of the ions. The metallic bonds between adjacent atoms, originating in the metal sublattice, add strength to the structure of such compounds. Carbides, nitrides, oxides and borides of the IV group of metals play an especially important role in the precipitation hardening of the V-VI group of metals.

Precipitation-hardened metals may be obtained by powder and granular metallurgy, by chemothermal treatment as well as by metallurgical methods used especially widely at present in making high-melting metal alloys.

Of all the physico-chemical hardening principles for high-melting metals, the most important are solid solution hardening of the metal base and increasing its strength by precipitated particles. The solid solution hardening of the OTsK metals in the high temperature region is facilitated by alloying with higher-melting metals that increase the melting temperature and the electron concentration of the alloy. The most efficient was the precipitation hardening of high-melting metals by high strength carbides, nitrides, oxides and borides of the IV-V group of metals that have the highest thermodynamic stability and strength. A rational basis for developing heat-resistant alloys may be a triple system consisting of metals of the V and VI group - a metal of the IV group-interstitial element, where the V-VI group metals are the basic components, while the high-melting compound $Me_{IV}X$ is the hardening phase that forms with it a quasi-binary eutectic system. The variable solubility of the compound in the matrix makes it possible to achieve by thermal treatment the precipitation hardening of the deformed alloys, and with a higher content of the hardening phase, up to the eutectic concentration -- to obtain high strength casting alloys.

Among the most high-melting metals, niobium is especially promising for developing heat-resistant alloys. It is distinguished by high plasticity, relatively low oxidizability and other useful characteristics. On the basis of new theoretical and experimental data, the possibility of efficient hardening of niobium and its alloys by precipitating particles of carbides, nitrides and zirconium and hafnium oxides was discovered. The patterns of forming and decomposing supersaturated solid solutions in two-phase niobium alloys is typical for the classical aging of alloys. In this connection, it is very important to be able to regulate the structure and properties of these alloys by thermal treatment. The combination of the optimal amount of precipitation hardening, phase and a rational mode of thermal treatment makes it possible to increase considerably the heat-resistance properties of modern niobium alloys.

On the basis of the phase (equilibrium) diagrams, and in connection with the physico-chemical theory of heat-resistance, it was found to be possible to systematize rationally a great amount of data on the precipitation hardening of vanadium, tantalum, chromium, molybdenum and tungsten alloys by high-melting compounds of group IV metals, as well as by niobium and tantalum compounds. Chapters 1 and 3 were written by V. K. Grigorovich and 2, 4, 5 -- by Ye. N. Sheftel'.

The authors express their deep gratitude to professor O. A. Bannykh, doctor of technical sciences, for his scientific editing of the book and very useful discussion of its basic concepts; K. P. Gurov, doctor of physico-mathematical sciences; O. G. Karpinskiy, candidate of physico-mathematical sciences; A. I. Kozlenkov,

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TABLE OF CONTENTS

	Page
Introduction	3
Bibliography	5
Chapter 1. Structure and properties of high-melting metals and compounds	7
1. Electronic structure, crystalline structure and physical properties of transition metals	7
2. Electronic structure, crystalline structure and physical properties of high-melting compounds	80
3. Physico-chemical substantiation for selecting hardening phases	120
Bibliography	124

FOR OFFICIAL USE ONLY

TABLE OF CONTENTS (continued)	Page
Chapter 2. Methods for obtaining dispersion hardened alloys	128
1. Powder methods	129
2. Methods based on the interaction between the solid metal and the gaseous medium	130
3. Metallurgical methods	133
Bibliography	136
Chapter 3. Physico-chemical principles of hardening high-melting metals	138
1. Deformation hardening	138
2. Solid-solution hardening	139
3. Precipitation hardening	147
4. Hardening by directed crystallization of eutectic alloys	170
Bibliography	173
Chapter 4. Precipitation hardening of alloys using niobium	175
1. Carbide hardening	175
2. Nitride hardening	212
3. Oxide hardening	241
4. Precipitation hardening of niobium alloys with high-melting carbides, nitrides and oxides	267
Bibliography	270
Chapter 5. Precipitation hardening of alloys using vanadium, tantalum, chromium, molybdenum and tungsten	277
1. Vanadium alloys	277
2. Tantalum alloys	279
3. Chromium alloys	281
4. Molybdenum alloys	285
5. Tungsten alloys	293
Bibliography	299

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2291

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